MAY 1972

DCIEM REPORT NO. 851

HIGH ALTITUDE LAND OPERATIONS

MAJOR G.W. GRAY
CAPTAIN E.M. HARTLIN

Operational Life Support Unit
DEFENCE AND CIVIL INSTITUTE OF ENVIRONMENTAL MEDICINE
1133 Sheppard Avenue West, P.O. Box 2000
DOWNSVIEW, Ontario.

DEFENCE RESEARCH BOARD — DEPARTMENT OF NATIONAL DEFENCE — CANADA

ABSTRACT

This short manual has been prepared for operational units in the event of a high altitude land operation. It is based primarily on the experience from the Mount Logan expeditions, and deals briefly with medical, communication and logistic problems encountered in such an operation.

HIGH ALTITUDE LAND OPERATIONS

TABLE OF CONTENTS

HIGH ALTITUDE LAND OPERATIONS

INTRODUCTION

Although it is unlikely that the Canadian Forces will become involved in a military operation at high terrestial altitudes, it is estimated that there are over ten million people living at altitudes above 12,000 feet throughout the world, many in areas of political instability. The possibility does exist for a Canadian Forces operation at high altitude in a peace-keeping or disaster response role, or in a search and rescue role within our own domain. This brief manual has been prepared in case of such an event, and is based primarily on experience gained from the Mount Logan exercises.

High altitude operations are taken to mean operations above 10,000 feet ASL. Although certain individuals are particularly sensitive to the effects of oxygen lack, few problems are encountered below this altitude apart from those inherent in mountainous terrain. Above 12,000 feet ASL, the problems due to altitude are more pronounced, and in general the severity increases proportionally with the altitude.

Operations in mountainous terrain, at high altitude, stress both the man and machine. This manual will deal briefly with medical, communications and logistics problems encountered on Mount Logan. It is written both for operational commanders and medical officers, but, of necessity, some parts of the medical section will deal with the specifics of treatment and will be of relevance only to medical officers.

MEDICAL PROBLEMS AT HIGH TERRESTIAL ALTITUDES

Most of the changes which occur in man exposed acutely to high altitude are secondary to the imposed hypoxia (lack of oxygen). The inspired partial pressure of oxygen at 10,000 feet, 15,000 feet and 17,500 feet (Mount Logan laboratory) are 110, 90 and 81 mm Hg. Although hypoxia has some immediate effects such as impaired mentation, the changes which occur secondary to hypoxia are more alarming and not immediately reversible with oxygen. These changes are not fully understood as yet, but involve shifts of electrolytes and fluids, readjustment of the blood and cerebrospinal fluid acid-base equilibrium, respiratory and circulatory adjustments, and compensatory mechanisms which evolve to deliver more oxygen to the tissues.

Immediate effects of hypoxia

Although immediate severe hypoxia (altitudes of 25,000 feet and greater) causes loss of consciousness and if severe enough, death, the effects of abrupt exposure to altitudes from 10,000 feet to 20,000 feet are less severe. Hypoxia induces hyperventilation through the peripheral chemoreceptors (chemical sensors in the circulatory system) and consequent hypocapnia (decreased carbon dioxide tension with increased alkalinity of the blood). The subjective symptoms on initial exposure to altitude are due to a combination of hypoxia and hypocapnia and in many ways are similar to drunkeness. These effects include euphoria, impaired judgement and memory, irrational ideation and uncontrolled emotional outbursts, dizziness, light-headness, and impaired psychomotor coordination. It is extremely important that operational commanders and medical officers be aware that everyone is affected, to varying degrees, and that they may be dealing with a platoon of men who appear to be drunk, and that they too will be in the same condition. In this situation, discipline, drills and check lists are extremely important. A thorough briefing of the expected effects emphasizing the need for concentration on discipline and drills may be of benefit. Hypoxia also reduces the ability to perform muscular work, and work worsens the hypoxia.

It is essential that as much preparation as possible be done at ground level to reduce the amount of work required at altitude. This is especially important during the period immediately after arrival at altitude, and up to several days afterwards. Operational commanders must be prepared to accept a greatly diminished work output from the man, and to enforce, if need be, a restriction of the level of physical activity for three to four days after arrival. In the long run manpower will be conserved by keeping physical activity at the required minimum after arrival at altitude.

Acute mountain sickness (AMS)

The initial euphoria of high altitude lasts for several hours, at which time, depending on the altitude, most unprotected people begin to develop acute mountain sickness. The onset is usually 6 to 12 hours after arrival at altitude. The most common symptom by far is headache, which is generally much worse in the morning. Other symptoms include: anorexia (loss of appetite), nausea, vomiting, insomnia, vivid nightmares, heart palpitations and arrhythmias, and extreme lethargy.

AMS varies in severity depending upon individual susceptibility, the rate of ascent, and altitude reached. In its severe form it is completely incapacitating, and those affected are incapable of caring for themselves.

The disease is generally self-limiting, and partial acclimatization occurs with relief of symptoms after one to several days. A small percentage do not improve or continue to get worse and require evacuation.

Psychological factors appear to play an important role both in the development of and recovery from acute mountain sickness. In any group there will be some who are very sick, some who are moderately sick, and some who are relatively well. If the group remains stable, and capable people help care for the incapacitated, the group survives. If the group fragments, the severely ill people can only get worse.

Treatment of acute mountain sickness is complicated by the fact that the medical officer is often as incapacitated as his patients. If at all possible, the medical officer should precede the troops to high altitude by several days to allow him to acclimatize. In addition, whenever possible, radio contact should be maintained with a medical unit at ground level, and treatment of patients at high altitude supervised by a medical officer at ground level familiar with the problems of high altitude.

Treatment should be aimed at prevention, and this can be accomplished in several ways:

a. Staged ascent. Although our experience with staging is at present limited, the following schedule is recommended. For altitudes below 11,000 feet, no staging is required. For altitudes greater than 11,000, one week at an altitude of 10,000 feet with gradually increasing daily exercise is recommended.

b. Drug prophylaxis. Acetazolamide 250 mg T.I.D. for 48 hours prior to ascent and for 36 hours after arrival at altitude has been shown to effectively reduce the severity and incidence of acute mountain sickness.

c. After arrival at altitude, a minimum of physical activity for several days and a fluid intake of at least 3 liters per day is felt to reduce the severity of acute mountain sickness. The fluid may be of any type, but fluids with a high caloric content such as fruit-flavored glucose solutions (Kool-Aid, Tang etc.) are preferable.

d. Maintenance of group identity and group spirit allays the psychological factors of AMS.

Definitive treatment is aimed at relief of symptoms, since the etiology is unknown. Headache should be treated with propoxyphene, codeine or meperidine. Vomiting must be vigourously treated with Gravol or Stemetil. Ingestion of antacids must not be allowed. A fluid intake of at least 3 liters per day must be maintained. The patient should sleep with the head elevated, as this helps reduce the severity of the headache. People with severe AMS should be examined at regular, frequent intervals, and if there are any signs of pulmonary edema or neurological complications developing, treatment instituted. Oxygen is not recommended for acute mountain sickness unless evacuation is planned, and it should then be given continuously until evacuation.

High altitude pulmonary edema

Pulmonary edema is an increase in the fluid in the extravascular tissues of the lung with eventual accumulation of the fluid in the alveoli or air sacs. The symptoms are a harsh, dry cough, with increasing shortness of breath, restlessness and mental confusion. The cough becomes productive of pink sputum, sometimes blood tinged, as the condition advances. Marked central (lips, ears, etc.) cyanosis (blueness) develops.

It is most common during the period of 1 to 3 days at altitude, but may occur later. It is associated with physical exertion, commonly developing after a period of intense physical activity at altitude. The incidence is much higher in people who have spent some time at altitude, descended to ground level for a period of one to two days, then reascended.

The earliest physical sign is rhonchi in the dependent lung zones, followed by rales. Signs of right heart failure are not present. The treatment must be rigorous, and includes:

a. 100% oxygen by mask

b. Diuretics - e.g. furosemide 20 mg I.V. or I.M. q4h

c. Morphine 15 mg q4h

d. Evacuation as soon as possible.

Neurological complications

A number of serious neurological conditions have been found to develop at high altitude. They may or may not be preceded by severe acute mountain sickness. Early recognition and treatment are important. These conditions, with the signs and symptoms, are listed below.

a. Cerebral Edema

(1)	Symptoms	(a)	severe headache unrelieved by analgesics
		(b)	increasing mental impairment, stupor or coma
(2)	Signs	(a)	papilledema
		(b)	cranial nerve palsies rarely occur
		(c)	usually no localizing signs
		(d)	seizures rarely occur

b. Ataxia of Gait

(1)	Symptoms	(a)	increasingly severe headache
		(b)	broad-based, unsteady gait
(2)	Signs	(a)	Rhomberg test is positive
		(b)	no other neurological signs

c. Difficulty with micturition and urinary retention. This condition may require catheterization.

The treatment of these conditions must be instituted as soon as they are recognized.

a. 100% oxygen by face mask.

b. Decadron 8 mg I.V. q4h

c. Furosemide 20 mg I.M. or I.V. q4h

d. Evacuation as soon as possible.

Retinal hemorrhage

About 15 – 30% of people flown to 17,500 feet have been found to develop retinal hemorrhages. There are asymptomatic unless they involve the macula and are discovered only by fundoscopic examination. These hemorrhages have been found to resolve after several weeks at ground level, leaving no sequelae unless they involve the macula, in which case a permanent scotoma may develop. There is no treatment.

Cold injury

Cold injury is not peculiar to altitude but altitude complicates cold by producing a peripheral vasoconstriction which makes the extremeties even more susceptible to cold injury. Standard procedures for cold protection learned in Arctic survival are sufficient at altitude if followed carefully. The miseries of acute mountain sickness and the mental impairment consequent to hypoxia make the individual prone to carelessness about cold protection, and strict personal discipline in these areas must be enforced.

Ultraviolet light injury

Altitude increases the quantity and intensity of solar radiation to which the body is exposed. The reflection of ultraviolet light from snow is four times that from water and eight times that from grass.

Without adequate protection, severe sunburn and/or snowblindness can occur with relatively short exposure. These are both entirely preventable. Eyes must be protected, preferably with tinted goggles which shield the sides of the eye. All exposed skin must be protected with a sun-screen compound containing 5% para-aminobenzoic acid in alcohol (e.g. Uval). Wide-brimmed hats and turtle-neck sweaters are advisable.

Snowblindness, once it occurs, is treated with cold compresses and a topical anaesthetic e.g. 1% cocaine solution or Ophthetic.

RADIO COMMUNICATIONS

Communications equipment for use in mountainous terrain, and particularly in high mountains, should combine reliability, light weight, and ease of operation. Very- and ultra-high-frequency radios are not, in general, acceptable for point-to-point communications because the line of sight between stations is very frequently blocked by peaks; they can be useful for emergency communication with aircraft. High frequency equipment should be selected with the objective of minimizing weight and power requirements. The intrinsic advantages of single side-band (A3J) over normal amplitude modulations (A3) are very obvious. Experience has shown that good quality single sideband transceivers with a peak envelop power output of about 10 watts, used with simple dipole antenna, provide reliable communications over ranges of up to 100 miles. Unfortunately at the time of writing no equipment in this category is currently available through normal Canadian military supply channels.

With low power solid state equipment if is unlikely that arcing or other problems associated with high altitude will occur. Equipment should be selected with due regard to temperature specifications, both storage and operating. Small radios can usually be brought to satisfactory operating temperature in a short time in a heated tent or shelter, or by warming between layers of clothing.

Dry batteries for low temperature operation should be of either nickle-cadmium or alkaline types. Mercury and the common carbon-zinc type should be avoided. Nickle-cadmium cells are useful to about 0°F. For best results, batteries should be kept considerably warmer than the lowest temperature at which they will operate. This is relatively easily accomplished by carrying them in an inside pocket while on the move and keeping them in a sleeping bag at night.

LOGISTICS

Food

Food becomes generally unpalatable during the first few days at high altitude. During this period a high fluid intake must be maintained. Powdered drinks which can be reconstituted (e.g. Tang, Kool-aid etc.) are satisfactory, and if sugar is added provide an additional source of energy during this anorexic phase. Melting sufficient snow becomes a major problem, and it is advisable to maintain a large reservoir of water on a stove continuously to which snow can added as necessary. For personnel too lethargic or ill to get their own drinks, it is important that a "buddy system" be instituted to ensure everyone has an adequate fluid intake. This should be a minimum of 3 liters per 24 hours and should be individually recorded. Caloric intake during this period can be supplemented by chocolate bars, candies, etc.

The choice of food after the first few anorexic days depends largely on the type of operation and the capabilities of the supply system. In general as much fresh food as is practical is advisable. Freeze-dried food is light and easily backpacked but tends to have a monotonous taste and texture. RP-4 rations have been used on Mount Logan and are satisfactory. They should be stored somewhere warm for about 12 hours prior to usage, since the canned food freezes completely and requires long periods of boiling to thaw.

The boiling point decreases as the altitude increases, and at 18,000 feet even hot drinks are no more than tepid.

Shelters

The ideal type of shelter of course depends upon the type of operation. At a fixed base operation, an ideal shelter in our experience consists of a collapsible framework of tubular metal or wood, covered with a double layer of a plastic material such as Daycron sailcloth, insulated with foam rubber. (e.g. Versadome, Full-truss shelters). These should be completed with a wooden floor. They can be heated with a propane heater and are quite comfortable.

The Canadian Forces ten-man Arctic Tent has proved inadequate on Mount Logan in that for two successive years, the center pole collapsed during a storm necessitating urgent evacuation. With an improved center support, this tent should be adequate. Ventilation is also a critical problem since even a small buildup of carbon monoxide will worsen the hypoxia.

Small portable tents such as the Bishop Ultimate are ideal for climbing parties. They combine lightness with a roomy inside and ease of erection.

It is worthy of note that the Canadian Forces supply system at present does not have either a semi-portable medium size building of the Versadome type, or, a small lightweight tent.

Equipment

a. Personal. A list of personal equipment issued to members of the annual Mount Logan projects is contained in Annex A. This consists mainly of winter combat clothing and Arctic clothing. This has been found to be satisfactory for warmth and protection, but is somewhat heavy and bulky for climbing. Of particular importance are the snow-goggles., sun glasses and sunscreen for protection against ultraviolet light injury. The ice axes are not standard issue and must be purchased by L.P.O.

b. Small Arms. The following weapons have been evaluated on Mount Logan:

(1) 9 mm pistol
(2) 9 mm SMG
(3) 7.62 mm rifle
(4) 7.62 mm rifle automatic

These were evaluated by test firing at base camp, then having the same individuals at the same ranges test fire on similar targets at altitude. All weapons functioned normally, and, in fact the scores at altitude were slightly better than at base camp.

c. General Equipment. Hypoxia and mountainous terrain stress both men and machines. The intellectual dulling effect of hypoxia makes the operation of equipment more difficult.

The internal combustion engine becomes less efficient as altitude increases, and at 17,500 feet it will not function unless supercharged or run with a pressurized fuel source e.g., propane. A 3.5 KW generator is run by a propane-driven engine at the Mount Logan laboratory.

Stoves and lanterns which use pressurized fuel sources function adequately. Coleman lanterns and stoves, and propane stoves and heaters are used on Mount Logan. Primus stoves have also been used but have not functioned as well as Coleman. Particular attention must be paid to adequate ventilation inside tents and shelters at altitude when combustion is occuring. Carbon monoxide is especially dangerous in this situation.

Various types of scientific equipment including recorders, amplifiers, nitralyser, retinal camera, centrifuges, and spectrophotometers have been operated at altitude with no problems due specifically to altitude.

A particular consideration of equipment left outside is that it can be rapidly buried in the mountain storms. Any equipment left outside should be properly marked.

Transportation

Travel in mountainous regions is complicated by the terrain, the weather and the altitude. Often the only means of movement is on foot, and this too can be dangerous for the unexperienced.

The internal combustion engine loses efficiency at a rate of 3% per thousand feet. Above about 10,000 feet engines must be supercharged or propane powered. Over snow vehicles are useful but must be used with extreme caution in glaciated areas because of crevasses covered by thin snow-bridges.

Both fixed-wing aircraft and helicopters can operate in mountainous areas. Helicopters are the most manoeuverable form of air support in this terrain. Bell Jet Ranger helicopters similar to the Kiowa have been used successfully on Mount Logan. Canadian Forces helicopters such as the CUHIH or CUHIN should have no problems operating at even higher altitudes.

Casualty Evacuation

Evacuation of personnel from mountainous regions is complicated by the vagaries of weather, since it is almost always accomplished by air. It is essential that the medical officer have sufficient supplies including oxygen to deal with any emergency at altitude and to give medical support to casualties for periods of up to several days. Radio contact with base camp is essential. Continously available, reliable air support is a necessity.

ANNEX "A"

PERSONAL KIT SUPPLIED TO MEMBERS OF MOUNT LOGAN PROJECT

1. Trousers man's combat light weight
2. Shirt – coat man's combat light weight
3. Trousers man's combat
4. Coat man's combat
5. Liner coat man's combat
6. Boots man's combat (water repellant)
7. Cap utility combat
8. Sweater turtleneck
9. Parka
10. Wind pants
11. Balaclava
12. Mitts
14. Socks wool 3 pr.
15. Goggles snow
16. Glasses sun
17. Boots mukluk c/w inserts (2 pr.) and insoles (2 pr.)
18. Snowshoes c/w bindings
19. Ice axe
20. Crampons
21. Bag sleeping temperate and arctic (complete)
22. Rucksack, universal (complete)
23. Kit bag
24. Sunscreen (e.g. Uval)
25. Lip salve

ANNEX "B"

MEDICAL EQUIPMENT AND SUPPLIES FOR MOUNT LOGAN

1. Pharmaceuticals

Acetazolamide (Diamox) tabs 250 mg.		
Amphogel tabs		
Ampicillin caps 250 mg.		
Anusol HC suppositories		
Atropine 0.6 mg/ml		1 ml ampoules
ASA plain tabs		
ASA with codeine gr 1/8 tabs		
Bradosol lozenges		
Butacaine ophth.		
Calcium gluconate	1 gm/10 ml	10 ml ampoules
Codeine phosphate tabs 30 mg.		
Chlorpheniramine tabs 50 mg.		
Chlorpromazine tabs 50 mg.		
Cepecol		
Dexamethasone phosphate 4 mg/ml		5 ml vials
Dextrose 50%		50 ml vials
Diazepam tabs 5 mg		
inj 5 mg/ml		2 ml ampoules
Dimenhydrinate tabs 50 mg.		
inj	10 mg/ml	30 ml vials
Diphenylhydantoin tabs 100 mg		
Dulcolax tabs		
Epinephrine HCl 1:1000		1 ml ampoules
Erythromycin tabs 250 mg		
Furosemide tabs 40 mg		
inj 10 mg/ml		2 ml ampoules
Heparin 1000 u/ml		10 ml vials
Hydrocortisone 1% with vioform		
ung. 15g tubes		
lotion 15 ml bottles		

Lomotil tabs	
Lanoxin tabs 0.25 mg	
inj 0.25 mg/ml	2 ml ampoules
Morphine sulphate 15 mg/ml	1 ml ampoules
Mycostatin suspension	
Neosporin otic 10 ml	
Nitroglycerin tabs 0.6 mg	
Ornade spansules	
Otrivin	
Penicillin V tabs 300 mg	
Pethidine 50 mg/ml	2 ml ampoules
Propantheline tabs 15 mg	
Procaineamide caps 250 mg	
Phenylbutazone tabs 100 mg	
Polybactrin aerosol	
Prochlorperazine 5 mg/ml	10 ml vials
Promethazine tabs 25 mg	
Propoxyphene HC1 pulvules 65 mg	
Secorbarbital caps 100 mg.	
Sodium chloride inj	25 ml vials
Tetracycline tabs 250 mg	
Tinactin powder	
Tetanus antitoxin	
Tetanus toxoid	
Xylocaine 20 mg/ml	50 ml vials
Xyclocaine ung 50 gm tubes	

2. Equipment

Two satchels complete with examining equipment and flashlights

Four sterile suture sets

Surgical scrub sponges with soap

Minor surgical set, sterile, incl. scalpel with blades

Sofra-tulle

ENT set

Razor blades

Bandaids, assorted

Adhesive tape, 1", 2" and 3"

Scotch tape

Cling gauze, assorted sizes

Elastocrepe bandages

Gauze sponges, sterile

Merthiolate 1:1000

Isopropyl alcohol 70%

Cetavolon 10%

Triangular bandages

Safety pins

Oral airways

Tongue depressors

Absorbent cotton

Eye pads, sterile

Eye shields

Finger splints

Tubular gauze dressings

Sutures, assorted, plain, silk, chromic

Phisohex

Syringes, 2 ml, 5 ml, 10 ml

Needles 18g, 21g. 25g

Gloves, sterile

Plaster gauze

Intravenous solutions – Ringer's lactate, NS, D5W

Intravenous tubing

Intravenous catheters

Urinary catheters and drainage/collecting system

Nasogastric tubes

Silver nitrate applicators

Fluorescein strips

Oxygen equipment

1. One transport cylinder of breathing oxygen per ten men at altitude.
2. One breakdown regulator with high and low pressure gauges for each transport cylinder
3. Three A20 diluter demand oxygen regulators for each transport cylinder.
4. One mask c/w suspension and helmet for each A20 regulator.
5. All necessary flexible tubing, connectors, accordian tubing, connectors.